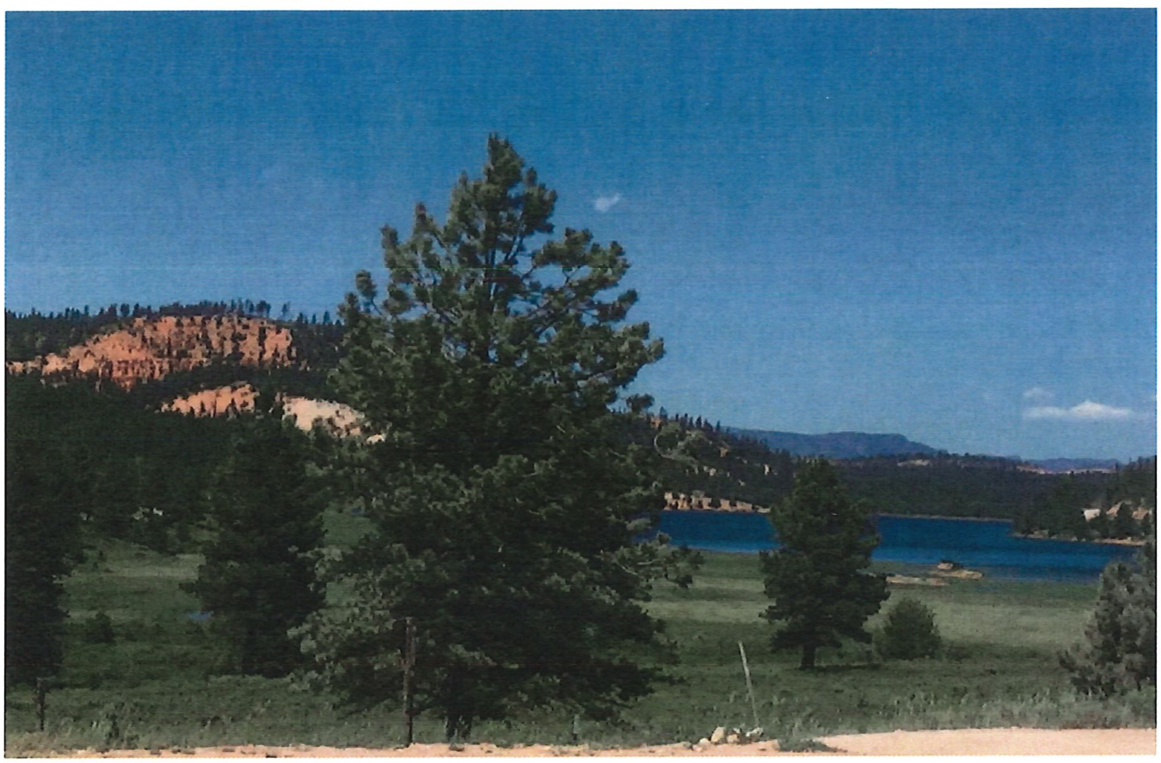
PETITION FOR GROUNDWATER QUALITY CLASSIFICATION, BRYCE CANYON AREA, GARFIELD COUNTY, UTAH

Submitted to Utah Water Quality Board by Garfield County Commission

Prepared by

Janae Wallace and Trevor Schlossnagle
Utah Geological Survey

April 14, 2021



Disclaimer: Although this product represents the work of professional scientists, the Utah Department of Natural Resources, Utah Geological Survey, makes no warranty, expressed or implied, regarding its suitability for a particular use. The Utah Department of Natural Resources, Utah Geological Survey, shall not be liable under any circumstances for any direct, indirect, special, incidental, or consequential damages with respect to claims by users of this product.

LICENSED PROFESSIONAL GEOLOGIST
JANAE J. WALLACE
5247814-2250
STATE OF UTAH

CONTENTS

FIGURES

TABLE

PLATES

INTRODUCTION

This is a formal petition to the Utah Water Quality Board submitted by the Utah Geological Survey on behalf of Garfield County to classify groundwater quality in the valley-fill aquifers of Johns and Emery Valleys under "Administrative Rules for Ground Water Quality Protection R317-6, December 1, 2019," Section 317-6-5, Ground Water Classification for Aquifers, Utah Administrative Code.

Johns Valley is in eastern Garfield County, central Utah, between latitudes 37º 24′ and 38º N. and longitudes 112º 15′ and 111º 52′ W. The main focus of the petition (figure 1) is Bryce Canyon City and the gently rolling, forested slope to the northwest and north; the East Fork Sevier River below Tropic Reservoir and associated side drainages, particularly East Creek; and Johnson Bench and Emery Valley, which comprise the southwestern end of Johns Valley. Bryce Canyon City is about 20 miles southeast of the community of Panguitch. The northwest rim of Bryce Canyon itself forms the southeastern study area boundary. Emery Valley is an intermontane basin that is bounded by the Sevier Plateau on the north and east, and the Paunsaugunt Plateau on the southwest, and opens to Johns Valley to the northeast. The East Fork Sevier River flows through Emery Valley from southwest to northeast and continues northeast through Johns Valley. The hand-dug Tropic Ditch taps into the East Fork Sevier River and transports water east through Water Canyon toward Tropic Valley (Davis and Pollock, 2010). Wells serving Bryce Canyon National Park are located in shallow aquifers south of the Ruby's Inn thrust fault. This classification document helps Garfield County recognize the value of their groundwater resource and aligns with their 2019 Economic Plan of planning and preparing for future water issues (Garfield County Economic Development Plan, 2019).

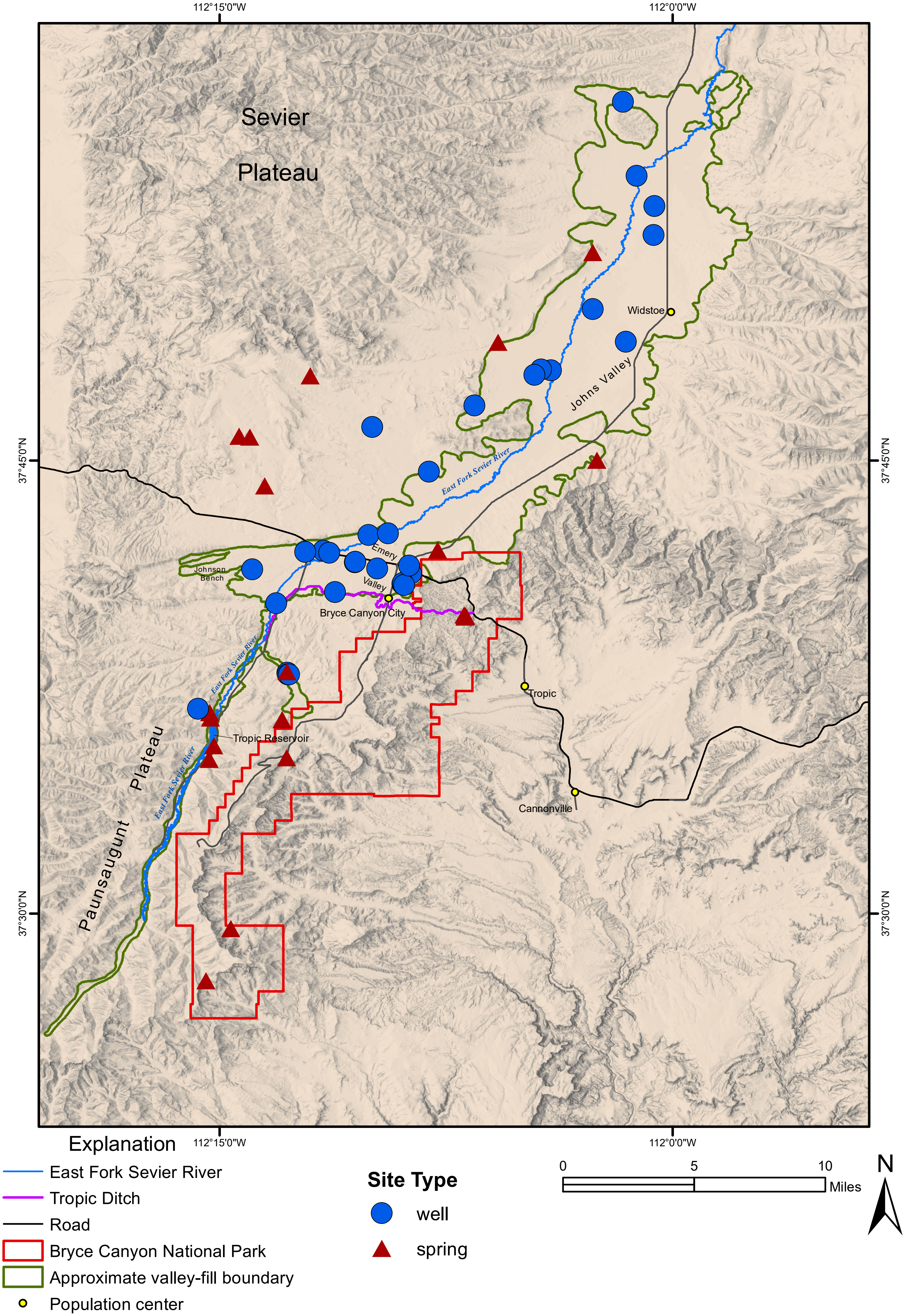


Figure 1. Location map of Johns and Emery Valleys, Garfield County, showing sampling locations for wells and springs.

POPULATION AND LAND USE

Garfield County had an estimated 2019 population of 5051 people, making it the least densely populated county in Utah (U.S. Census Bureau, 2019). Most of the population in Johns and Emery Valleys is concentrated in and around Bryce Canyon City. Johns and Emery Valleys also have some second homes, cabins, and resort lodging that are occupied only part of the year. Seasonal population added to the census-derived population increases the mean population. Bryce Canyon City had an estimated projected 2020 population of 232 people (Utah Governor's Office of Management and Budget, 2012). The community of Bryce Canyon City is an area of active tourism, with recreation and leisure activities centered within or near Bryce Canyon National Park (BCNP). The surrounding community of Bryce Canyon City is residential and commercial, and typically revolves around Ruby's Inn and catering to tourism. Some other land uses include irrigated crop lands, small scale animal feeding operations, gravel mining, and waste disposal.

FACTUAL DATA

Sufficient information is available to classify the valley-fill aquifer in the Bryce area. Data required to formally petition the Utah Water Quality Board were partly obtained from previously published studies (listed in the References section of this petition). Most of the information required for classification is presented on maps and in data tables submitted with this petition, including:

- Plate 1 - Groundwater quality map showing total-dissolved-solids concentrations;
- Plate 2 - Groundwater quality classification map showing groundwater quality classification, well locations, and groundwater flow direction; and
- Plate 3 - Potential-contaminant-source map.

In addition, a previously released publication containing valuable information about the upper Sevier drainage basin, which includes Johns and Emery Valleys, is provided with this petition:

- Ground-Water Hydrology of the Upper Sevier River Basin Beaver Valley Area, South-Central Utah and Simulation of Ground-Water Flow in the Valley-Fill Aquifer in Panguitch Valley (Thiros and Brothers, 1993; https://www.waterrights.utah.gov/cgi-bin/docview.exe?Folder=TP20-6-511&Title=Technical+Publication+102).

GEOLOGIC SETTING

Johns and Emery Valleys are in the Colorado Plateau physiographic province. Johns Valley, situated between the Escalante Mountains and Sevier Plateau, is a topographic depression in which valley-fill sediment has accumulated from the East Fork Sevier River and alluvial fans and side drainages emanating from the surrounding hills. Emery Valley, a southwestern extension of Johns Valley is situated between the Sevier and Paunsaugunt plateaus. The valley fill forms the principal aquifer of both valleys. Bryce Canyon is a major geologic feature to the south of both valleys.

Geologic units in the study area are Quaternary unconsolidated deposits, Tertiary volcanic and sedimentary rocks, and Cretaceous sedimentary rocks. The predominant geologic units are Quaternary valley fill, the Tertiary Mount Dutton, Brian Head, and Claron Formations, and the Cretaceous Kaiparowits, Wahweap, and Straight Cliffs Formations.

The Quaternary unconsolidated deposits include gravel, sand, and clay derived from adjacent hills and mountains that were deposited in alluvial-fan, fluvial, and mass-movement environments.

The Oligocene-Miocene Mount Dutton Formation is moderately resistant to nonresistant volcanic mudflow breccia consisting of angular to subrounded, matrix-supported, pebble- to boulder-sized clasts of dacitic to andesitic volcanic rock in a muddy to sandy matrix (Mackin and Rowley, 1976; Maldonado and Williams, 1993a, 1993b; Rowley and others, 1994). In the northwestern part of Johns Valley in the Sevier Plateau, Mount Dutton Formation is light- to dark-gray and brown, andesitic to dacitic volcanic mudflow breccia and lesser interbedded volcaniclastic conglomerate and tuffaceous sandstone (Biek and others, 2015). Exposures in the Sevier Plateau are the alluvial facies of the Mount Dutton Formation, re-interpreted as part of the Markagunt gravity slide, about 2000 feet thick on the southern end of the Sevier Plateau (Rowley and others, 1987; Biek and others, 2015).

The Eocene-Oligocene Brian Head Formation is mapped as non-tuffaceous sandstone and conglomerate, volcanic mudflow breccia, mafic lava flows, volcaniclastic sandstone with minor limestone and chalcedony, ash-flow tuff (Biek and others, 2015). The unit consists dominantly of yellowish-gray and light-gray, cross-bedded, tuffaceous sandstone with interbedded pebble- to boulder-sized conglomerate, sandstone, and minor limestone and mudflow breccia (Maldonado and Moore, 1995).

The Eocene-Paleocene Claron Formation in the study area consists of the white limestone member and pink member. The Claron Formation consists of mudstone, siltstone, sandstone, limestone, and minor conglomerate deposited in fluvial, floodplain, and lacustrine environments of an intermontane basin (Mullet, 1989; Ott, 1999; Biek and others, 2015). The pink member is dominantly fluvial, while the white member is both fluvial and lacustrine (Goldstrand,1994; Bown and others, 1997). The lower white member consists of micritic limestone similar to the upper white limestone interval and forms a cliff or steep, ledgy, white slope. The lower limestone unit has a maximum thickness of about 300 feet at Bryce Point in BCNP (Bowers, 1990), and about 160 feet thick to the north on the southwest flank of the Sevier Plateau (Biek, 2015). Within BCNP at Inspiration Point, the lower limestone member is mostly white, pink, and pale-orange, slope-forming mudstone and siltstone with only minor limestone (Knudsen and others, in preparation).

The upper limestone unit of the white member is white, pale-yellowish-gray, pinkish-gray, and very pale orange micritic limestone and uncommon pelmicritic limestone, and typically about 80 to 100 feet thick on the southern flank of the Sevier Plateau (Biek and others, 2015). The pink member consists of micritic limestone, calcite-cemented sandstone, calcareous mudstone, and minor pebbly conglomerate that weather to colluvium-covered ledgy slopes. The pink member is about 600 feet thick at Bryce Canyon National Park (Biek and others, 2015).

The Kaiparowits Formation is the light-brown, very fine grained sandstone and gray sandy mudstone (above the capping sandstone member of the Wahweap Formation) southwest of Tropic Reservoir (Bowers, 1990). The Kaiparowits Formation was deposited as an eastward-prograding clastic wedge in a relatively wet, subhumid alluvial plain with periodic to seasonal aridity near the western margin of the Late Cretaceous Western Interior Seaway (Roberts, 2007).

The Late Cretaceous Wahweap Formation overlies the Straight Cliffs Formation in the drainage basin; these two units are very similar, especially near their contact, and are commonly lumped together as an undivided map unit. The Wahweap Formation is mostly fine-grained sandstone, siltstone, and mudstone deposited in braided and meandering river and floodplain environments of a coastal plain (Lawton and others, 2003). Around Tropic Reservoir, because of extensive vegetative cover and poor geomorphic expression, three members of the Wahweap Formation are mapped as undivided, with the exception of the distinctive capping sandstone (Knudsen and others, in preparation).

The Late Cretaceous Straight Cliffs Formation consists of the Drip Tank and John Henry's Members in the study area. On the Paunsaugunt Plateau, the Drip Tank Member is white to light-gray, fine- to medium-grained quartzose sandstone, and, in the upper part of the unit, pebbly sandstone and pebbly conglomerate (Biek and others, 2015). The John Henry Member consists of variegated, gray, brown, and reddish-brown mudstone and thin- to thick-bedded, grayish-orange to yellowish-brown, fine-grained subarkosic sandstone and forms ledgy slopes on the eastern margin of the BCNP boundary; in the area around Bulldog Hollow near the town of Tropic, the John Henry Member is stacked or amalgamated sandstone in the upper part of the unit. North of Tropic, a prominent 20- to 40-foot coal-rich interval is mapped as a marker bed (Knudsen and others, in preparation).

The principal structural elements of Johns Valley (Biek and others, 2015) include the Paunsaugunt fault zone, a northwest-side-down Quaternary normal fault that strikes northeast through Johns Valley along the eastern margin of the study area; the Pine Hills and Rubys Inn thrust faults, which strike east-west and bound the northern and southern boundaries, respectively, of Emery Valley; and the Johns Valley thrust fault northwest of Flake Mountain, which strikes northeast through the central part of Johns Valley in the northern part of the study area.

GROUNDWATER CONDITIONS

Introduction

Groundwater in Johns and Emery Valleys occurs in two types of aquifers: (1) valley-fill deposits, and (2) bedrock (figure 2). This study focuses on the valley-fill aquifer, which consists primarily of clay, silt, sand, and gravel and ranges in thickness from tens of feet to 200 feet. Tertiary and Cretaceous rocks may also yield water to some wells, but the number of wells screened in and water production from these units before this study were unknown. The limestone of the Claron Formation is part of the bedrock aquifer, along with Cretaceous sandstone formations, in the Emery Valley area. The East Fork Sevier River is sourced in the Paunsaugunt Plateau, enters the study area from the

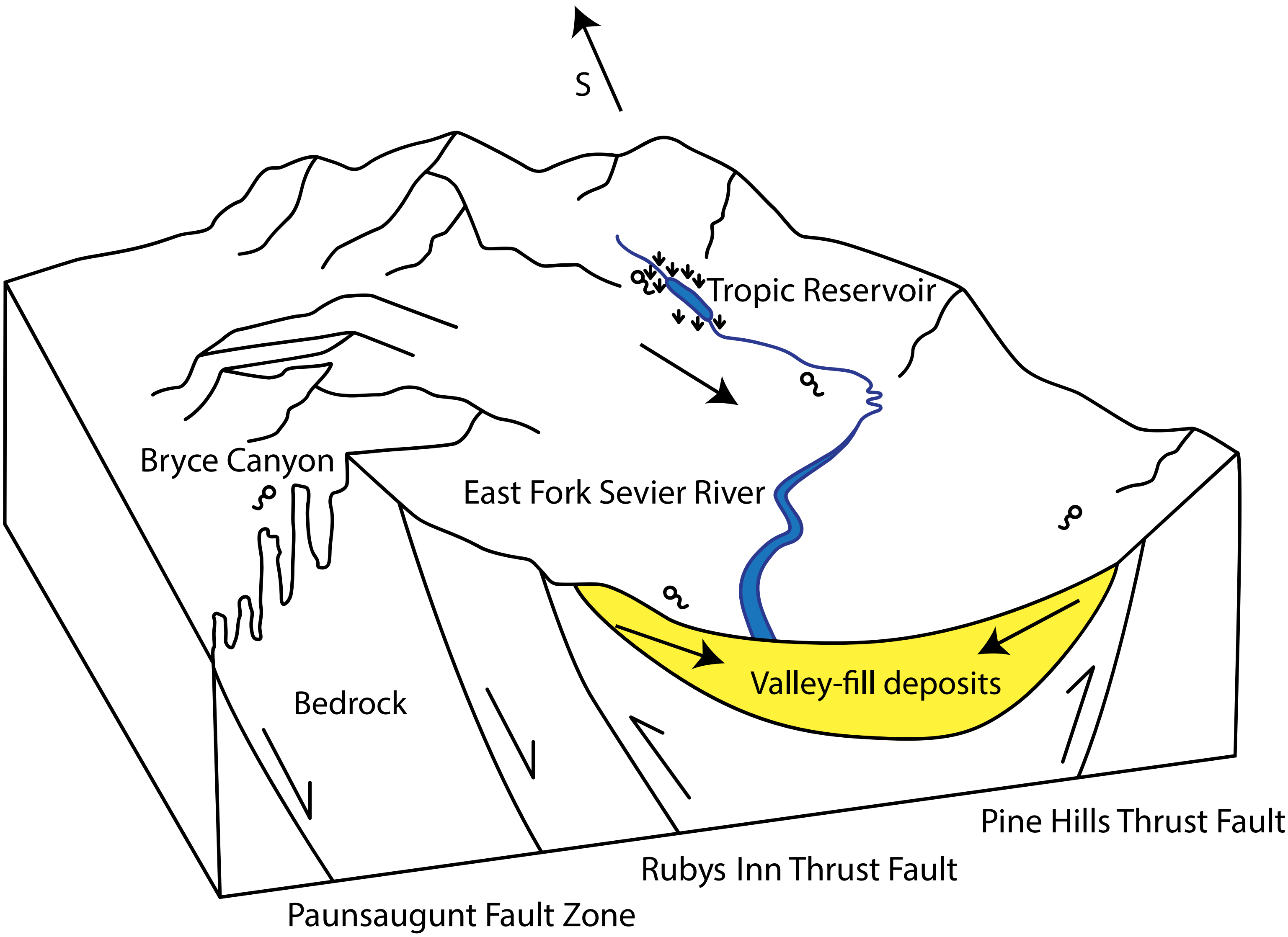


Figure 2. *Schematic block diagram showing groundwater conditions in Johns and Emery Valleys. Arrows indicate groundwater flow direction.*

south, and flows northeast through the study area in Johns and Emery Valleys. During seasonal irrigation (April to October), water from the East Fork Sevier River is diverted to the Tropic Ditch below Tropic Reservoir where it flows within a canal/ditch system toward the community of Tropic to the east.

Valley-Fill Aquifer

Occurrence

The valley-fill aquifer is an important source of drinking water in the Bryce Canyon City area. In general, the valley fill consists predominantly of stream alluvium and alluvial-fan deposits (Thiros and Brothers, 1993), which are generally coarser grained near basin margins, and finer grained along the lower reaches of streams and creeks and along floodplains in the central parts of the basin. Drillers' logs of water wells indicate that some wells intersect clay lenses, but no clay layers are extensive enough to act as a single, continuous confining layer, and the valley-fill aquifer is dominantly unconfined. Based on a review of well logs from the Utah Division of Water Rights database, the valley fill ranges in thickness from tens of feet near the basin margins to more than 100 feet below the valley floor, and up to 200 feet on Johnson Bench. Most valley-fill deposits are Quaternary stream alluvium (map unit Qaly of Biek and others, 2015), which consists of stream alluvium and stream-terrace alluvium and likely has high transmissivity.

Depth to water in the principal aquifer ranges from near surface level along the upper East Fork Sevier River to no greater than 200 feet. Unconfined groundwater is typically less than 10 feet deep adjacent to floodplains and shallow tributary alluvial valleys, and in low-lying areas where phreatophytes and springs are common. Groundwater flows primarily from recharge areas and from Tropic Reservoir, and generally flows to the north-northeast, parallel to the East Fork Sevier River.

Groundwater Quality

Water quality and the potential for water-quality degradation are critical elements determining the extent and nature of future development in Johns and Emery Valleys. Most development is on unconsolidated valley-fill deposits, the primary source of groundwater. Unlike other Utah communities, the population of Bryce Canyon City decreased between 2010 and 2016, from 198 to 182 residents (Town Charts, 2018; http://www.towncharts.com/Utah/Demographics/Bryce-Canyon-City-town-UT-Demographics-data.html). However, this is an area of active tourism and therefore, potential future growth. Increased demand on drinking water would warrant careful land-use planning and resource management to preserve Johns and Emery Valleys' surface and groundwater resources. A preliminary search of water-quality data for the study area yielded only one sample from the Utah Department of Agriculture and Food (UDAF). A sample from a well in the northeastern corner of the study area taken in 2003 had a total-dissolved-solids (TDS) content of 218 mg/L, a pH of 8.5, and no constituents that exceeded secondary drinking-water or agricultural standards.

GROUNDWATER-QUALITY CLASSIFICATION DATA

To facilitate this groundwater-quality classification, the Utah Geological Survey sampled 32 wells and 22 springs during autumn 2018, spring 2019, autumn 2019, and spring 2021. These sites have water in both alluvial and bedrock material, though the aquifer classification for this petition is for the valley fill only, we include these other sites to provide a more detailed background for water quality for the entire area.

We measured specific conductance in groundwater from 32 wells and 22 springs, groundwater from 24 wells and 16 springs was analyzed for general chemistry (appendix A), and groundwater from 27 wells and 16 springs was analyzed for nutrients by the Utah Department of Epidemiology and Laboratory Services (appendix A). We augmented our data with 14 sites within the USGS National Water Information System (NWIS) and UDAF databases for dissolved metals and pesticides. Select solutes analyzed for these sites include aluminum, arsenic, boron, barium, bromide, copper, lead, selenium, iron, manganese, fluoride, zinc, lithium, silicon, and uranium. Overall, water quality is characterized as calcium-magnesium bicarbonate type water (figure 3).

Total-Dissolved-Solids Concentrations

The Utah Water Quality Board's drinking-water quality (health) standard for TDS is 2000 mg/L for public-supply wells. The secondary groundwater quality standard is 500 mg/L (U.S. Environmental Protection Agency, 2006) and is primarily due to imparting a potential unpleasant taste to the water (Bjorklund and McGreevy, 1971). Plate 1 shows the distribution of TDS in Johns and Emery Valleys' valley-fill aquifer. Based on data from groundwater samples from 32 wells (26 from TDS and six wells from TDS converted from specific conductance data), TDS concentrations in the valley-fill and bedrock aquifers of Johns and Emery Valleys range from 151 to 530 mg/L, with no wells exceeding 1000 mg/L TDS and an overall average TDS concentration of 282 mg/L (appendix A, plate 1). The TDS concentration of 530 mg/L is from one of three bedrock

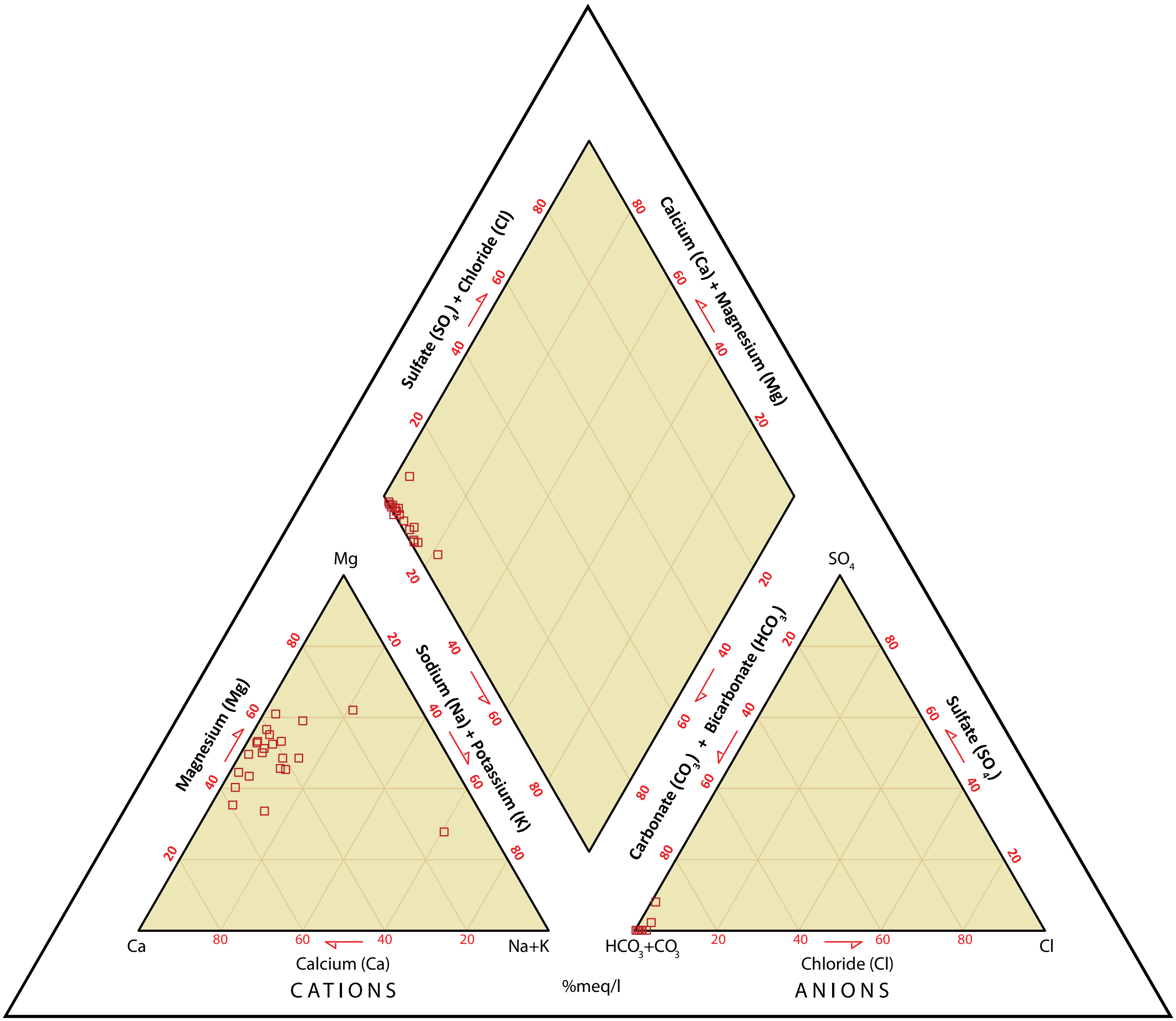


Figure 3. *General chemistry in Johns and Emery Valleys characterized by an overall calcium-magnesium bicarbonate water type.*

wells perforated in bedrock only, which is not classified as part of this aquifer petition (the other bedrock wells yield TDS of 192 and 416 mg/L). One well has a TDS of 514 mg/L (site 48; plate 1) that has perforations in both the alluvium and bedrock, just above the 500 mg/L Pristine quality cutoff, but because a single well cannot be classified, the overall valley-fill aquifer remains Class IA. The range of specific conductance for 54 wells and springs is from 240 to 884 µS/cm. We computed TDS concentrations from specific conductance measurements using a conversion factor of 0.63. This conversion factor was calculated by comparing TDS and specific conductance data collected in this study (figure 4). Using this conversion factor, we calculated TDS values for six wells and six springs sampled for this study. The converted TDS values range from 151 to 377 mg/L; all of these samples are below 500 mg/L and are classified as Pristine water quality as defined by the Utah Water Quality Board.

Nitrate Concentrations

The groundwater quality (health) standard for nitrate is 10 mg/L (U.S. Environmental Protection Agency, 2006). More than 10 mg/L of nitrate in drinking water can result in a condition known as methemoglobinemia, or "blue baby syndrome" (Comley, 1945; Fan and others, 1987; Bouchard and others, 1992) in infants under six months old and can be life threatening without immediate medical attention (U.S. Environmental Protection Agency, 2002). This condition is characterized by a reduced ability for blood to carry oxygen. Studies involving lab rats ingesting a combination of nitrate and heptamethyleneimine in drinking water reported an increase in tumor occurrence (Taylor and Lijinsky 1975). However, epidemiological investigations

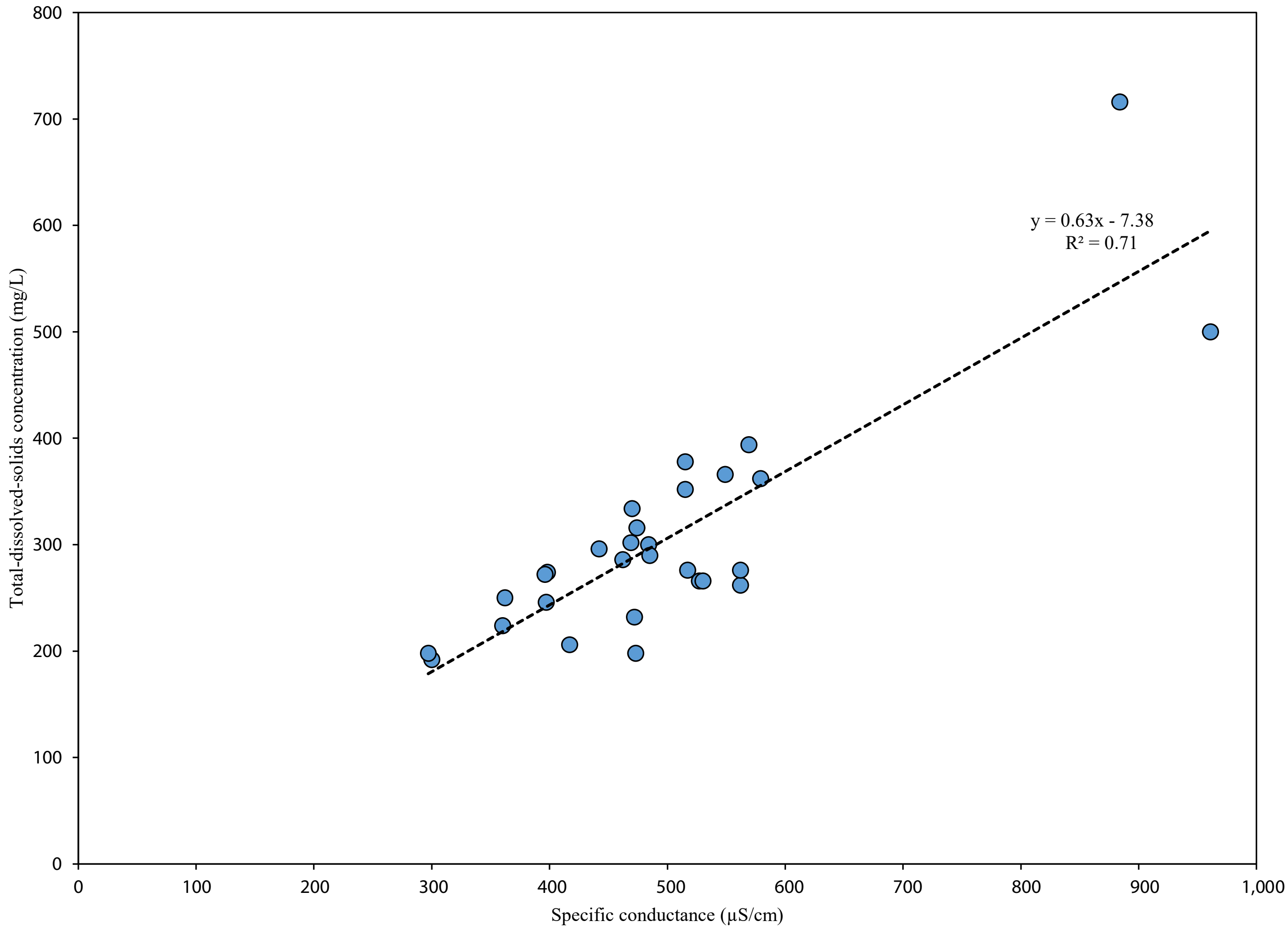


Figure 4. *Specific conductance versus total-dissolved-solids concentration data for 29 wells in Johns and Emery Valleys. R-squared is 0.71. Based on Hem's (1985) equation for estimating TDS from specific conductance: KA=S, where K=specific conductance, S=TDS, A ranges from 0.4 to 0.8 with an average A=0.63 (slope) used as the conversion factor to compute TDS in the study area.*

involving human beings have shown conflicting evidence. Stomach cancer in human beings associated with nitrate from drinking water has been reported in Columbia and Denmark (Cuello and others, 1976, Fraser and others, 1980). Conversely, investigations in the United Kingdom and other countries indicate no correlation exists between nitrate levels and cancer incidence (Forman, 1985; Al-Dabbagh and others, 1986; Croll and Hayes, 1988, Taneja, 2017).

Based on data from groundwater samples from 27 wells and 16 springs, nitrate-as-nitrogen concentrations range from less than 0.1 to 1.47 mg/L, with 42% of wells and springs yielding groundwater having concentrations below 0.1 mg/L, and an overall average nitrate concentration of 0.35 mg/L (appendix A). No apparent trend in the distribution of nitrate concentrations exists; the highest concentrations (1.06 and 1.47 mg/L) are likely attributed to proximity to stables/corrals and downgradient from septic systems (plate 3). All but one well had ammonia concentrations below the detection limit (0.05 mg/L); the well having a detectable ammonia concentration is below the Utah and EPA standard (appendix A).

Other Constituents

Based on the data presented in appendix A, no water from wells exceeded primary water-quality standards.

PROPOSED CLASSIFICATION

Under "Administrative Rules for Ground Water Quality Protection R317-6, December 1, 2019," Section 317-6-3, Ground Water Classes, Utah Administrative Code, Utah's groundwater quality classes are based on TDS concentrations as shown in table 1. Two other classes, IB and IC, are not based on groundwater chemistry. Class IB groundwater, called Irreplaceable groundwater, is a source of water for a community public drinking-water system for which no reliable supply of comparable quality and quantity is available because of economic or institutional constraints; this class has not been considered as part of this petition. Class IC groundwater, called Ecologically Important groundwater, is a source of groundwater discharge important to the continued existence of wildlife habitat. Groundwater protection levels for classes IA and IB, as set under "Administrative Rules for Ground Water Quality Protection R317-6, December 1, 2019," Section 317-6-4, Ground Water Class Protection Levels, Utah Administrative Code, are more stringent than for other groundwater quality classes.

Garfield County is petitioning the Utah Water Quality Board to classify the principal valley-fill aquifer in Johns and Emery Valleys as shown on plate 2. The classification is based on data from groundwater from the 32 wells we sampled for TDS and augmented by UDAF and NWIS data from wells presented in appendix A. Where insufficient data exist, extrapolation of groundwater quality conditions is required. We based the extrapolation on local geologic characteristics.

Class IA- Pristine groundwater: TDS concentrations in the valley fill of Johns and Emery Valleys range from 151 to 512 mg/L (appendix A). Class IA areas are mapped throughout all of Johns and Emery Valleys (plate 2). Areas having Pristine water quality cover 100% of the total valley-fill material.

Table 1. *Groundwater quality classes under the Utah Water Quality Board total-dissolved-solids (TDS)-based classification system (modified from Utah Division of Water Quality, 1998).*

Groundwater Quality Class	**TDS Concentration**	**Beneficial Use**
Class IA/IB[1]/IC[2]	Less than 500 mg/L[3]	Pristine/Irreplaceable/ Ecologically Important
Class II	500 to less than 3000 mg/L	Drinking Water[4]
Class III	3,000 to less than 10,000 mg/L	Limited Use[5]
Class IV	10,000 mg/L and greater	Saline[6]

[1]Irreplaceable groundwater (Class IB) is a source of water for a community public drinking-water system for which no other reliable supply of comparable quality and quantity is available due to economic or institutional constraints; it is a groundwater quality class that is not based on TDS.
[2]Ecologically Important groundwater (Class IC) is a source of groundwater discharge important to the continued existence of wildlife habitat; it is a groundwater quality class that is not based on TDS.
[3]For concentrations less than 7000 mg/L, mg/L is about equal to parts per million (ppm).
[4]Water having TDS concentrations in the upper range of this class must generally undergo some treatment before being used as drinking water.
[5]Generally used for industrial purposes.
[6]May have economic value as brine.

CURRENT BENEFICIAL USES

In the study area, groundwater from the valley-fill aquifer is an important source of domestic and municipal culinary water for people living within the valley (Burden and others, 2007). Domestic use of municipal groundwater supply in 2018 was 2.3%; commercial use was 93.1%, and institutional use was 4.7% (Utah Division of Water Rights, 2019). Countywide, the three public-supply systems located in Johns and Emery Valleys use about 18.1% of total Garfield County municipal water supply (286 acre-feet compared to 1586 acre-feet of water by the entire county during 2018).

WATER-SUPPLY WELLS

There are 50 approved water wells in Johns and Emery Valleys based on Utah Division of Water Rights records, nine of which are public-supply wells (Deidre Beck, Division of Drinking Water, personal communication, February 2019). The location of all wells is shown on plate 2.

POTENTIAL CONTAMINANT SOURCES

We mapped potential groundwater contaminant sources including facilities related to mining, manufacturing, agricultural practices, and wastewater-treatment facilities (plate 3; appendix B). We mapped 104 potential contaminant sources in the following categories in Johns and Emery Valleys:

(1) Mining, which includes abandoned and active gravel mining operations and borrow pits that potentially contribute metals, solvents, and petroleum products.

(2) Agricultural practices, which consist of irrigated and non-irrigated crops, irrigation wells, active and abandoned animal feedlots, corrals, and stables/barnyards that potentially contribute nitrate.

(3) Industrial facilities that potentially contribute pesticides, metals, solvents, petroleum products, and polychlorinated biphenyl (PCB) spills associated with a variety of sources such as transportation facilities, salt storage facilities, transformer (power) stations, and cell towers.

(4) Small businesses, such as hotels, restaurants, retail shops, and commercial shooting ranges, some of which may contribute pollutants such as metals and solvents.

(5) Large lawns, including parks and cemeteries, that may contribute fertilizer and pesticides.

(6) Service stations including auto shops and gas stations that may contribute petroleum products, antifreeze, and solvents, and junkyard/salvage operations that may contribute pollutants such as metals and solvents.

(7) Waste-disposal sites that may contribute pollutants such as solvents, metals, and nitrate.

(8) Above-ground storage tanks that may contribute pollutants such as petroleum, metals, and solvents.

In addition to the above-described potential contaminants, septic tank soil-absorption systems are also present in Johns and Emery Valleys. Since 1978, 39 wastewater permits have been issued or are in process in our study area (Jeremy Roberts, Southeastern Utah Public Health Department, verbal/written communication, August 15, 2019). Outside of towns and cities, septic-tank systems in Garfield County, until recently, have been widely spaced. Within Bryce Canyon National Park, a few septic tanks still exist (Moyle Jones, personal communication, November, 2020) but were likely more prevalent historically within the Bryce Canyon City community. These domestic wastewater facilities could have contributed to nitrate concentrations in groundwater in the vicinity of town. Septic-tank systems may contribute contaminants such as nitrate and solvents.

EXISTING POLLUTION SOURCES

Existing pollution sources include those contaminants that have been documented and/or are currently being treated; potential contaminants address pollutants that have the potential to degrade groundwater. There are no known existing pollution sources in Johns and Emery Valleys.

GROUNDWATER FLOW

To construct potentiometric surfaces, we measured water levels in wells at four different times: autumn 2018, spring 2019, autumn 2019, and spring 2020. We calculated the elevation at most wells using a Trimble high-precision GPS having vertical accuracy of 10 centimeters. Water-level elevation at each well was determined by subtracting the measured depth to water from the land-surface elevation obtained from the GPS. The potentiometric surface for the autumn 2018 season shows conditions with water levels at their lowest measurement levels (in most wells); we use data from this potentiometric surface map to determine groundwater flow direction— perpendicular to contours on the

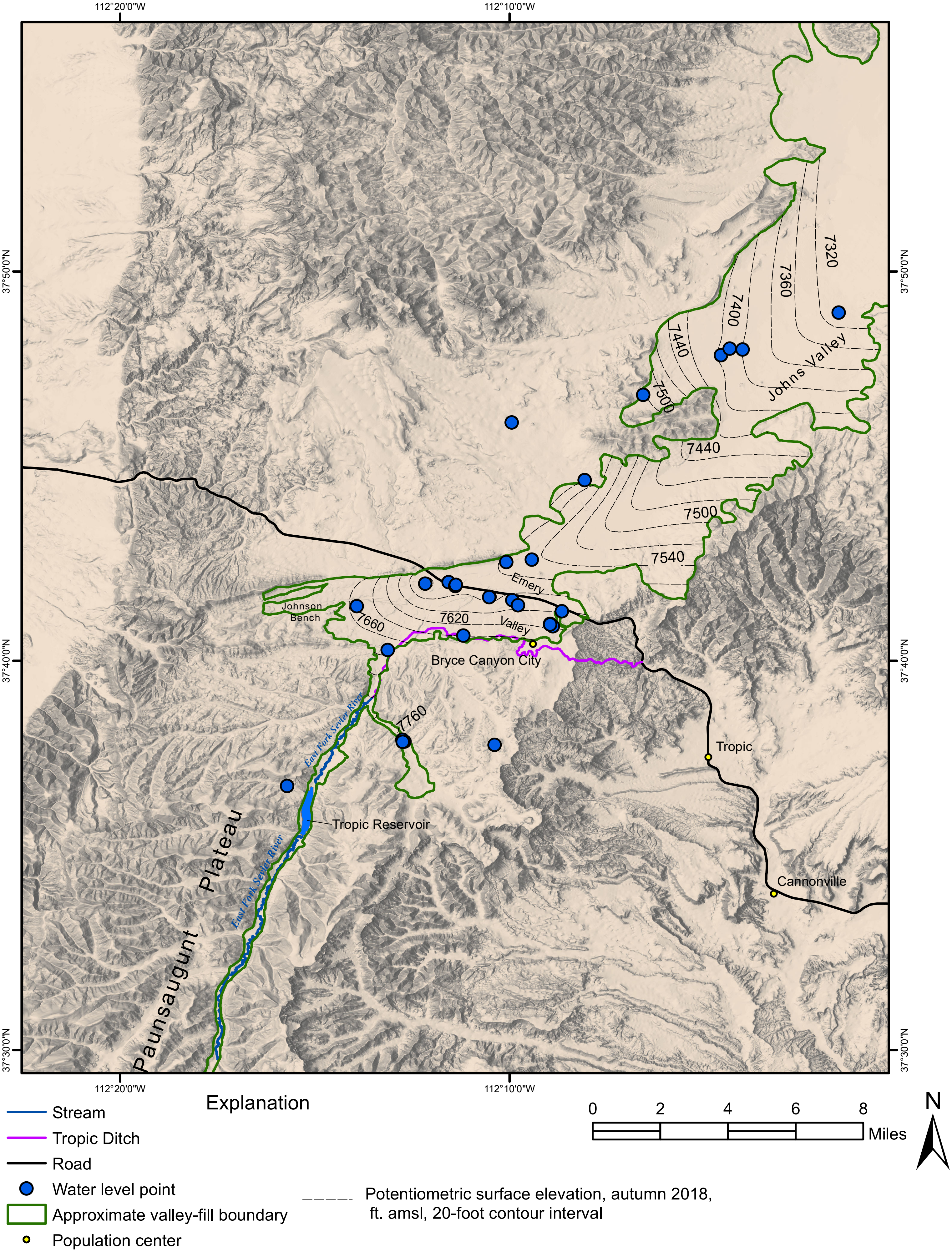


***Figure 5.** Potentiometric surface map of water wells from autumn 2018. Overall direction of groundwater flow is to the north-northeast.*

potentiometric surface map (figure 5; plate 2). Groundwater flows from Tropic Reservoir to the north and from the valley margins toward the valley center, along the East Fork Sevier River, and eventually downstream (north and then northeast) toward Black Canyon where the East Fork Sevier River exits Johns Valley (figure 5; plate 2).

SUMMARY

Groundwater is the principal source of drinking water in Johns and Emery Valleys. While most of the development in Bryce Canyon City is on community sewer and public-water systems, most development in the county portion has single-family homes, with each lot-owner typically using their privately owned water well for water supply and a septic-tank system for wastewater disposal. These septic-tank systems are on valley-fill deposits, which are a major drinking-water aquifer for the valley residents. Groundwater quality classification is a tool that can be used in Utah to manage potential groundwater contamination sources and protect the quality of groundwater resources. The results of the proposed groundwater quality classification for the valley indicate that the valley-fill aquifer contains mostly high-quality groundwater resources that warrant protection. One hundred percent of the valley-fill in the area is classified as having Class IA groundwater based on chemical analyses of water from 54 wells and springs sampled during autumn 2018, spring 2019, and spring 2021.

ACKNOWLEDGMENTS

This study was funded by the Utah Division of Water Quality, Utah Division of Water Rights, National Park Service, and the Utah Geological Survey. We thank the landowners for allowing us to access their property and sample their wells. We thank Fred Syrett for allowing access to Ruby's Inn well systems. We thank Moyle Johnson, William Jones, and Wayne Sawyer of Bryce Canyon National Park for accompanying us to access their public supply wells. We thank Kaden Figgins (County Planner, Garfield County) for his input. We thank Hugh Hurlow, Stephanie Carney, and Mike Hylland (UGS) for providing comments to the report.

REFERENCES

Al-Dabbagh, S., Forman, D., Bryson, D., Stratton, I., and Doll, R., 1986, Mortality of nitrate fertilizer workers: British Journal of Industrial Medicine, v. 43, 507 p.

Anderson, J.J., and Rowley, P.D., 1975, Cenozoic stratigraphy of southwestern high plateaus of Utah, *in* Anderson, J.J., Rowley, P.D., Fleck, R.J., and Nairn, A.E.M., editors, Cenozoic geology of southwestern high plateaus of Utah: Geological Society of America Special Paper 160, p. 1–51.

Biek, B., Rowley, P.D., Anderson, J.J., Maldanado, F., Moore, D.W., Hacker, D.B., Eaton, J.G., Hereford, R., Sable, E.G., Filkhorn, H.F., and Matyjasik, B., 2015, Geologic map of the Panguitch 30 x 60 quadrangle, Garfield, Iron, and Kane Counties, Utah: Online https://ugspub.nr.utah.gov/publications/geologicmaps/30x60quadrangles/m-270.pdf, scale 1:62,500.

Bjorklund, L.J., and McGreevy, L.J., 1971, Ground-water resources of Cache Valley, Utah and Idaho: Utah Department of Natural Resources Technical Publication No. 36, 72 p.

Bouchard, D.C., Williams, M.K, and Surampalli, R.Y., 1992, Nitrate contamination of groundwater: Sources and potential health effects: American Water Works Association Journal, v. 84, no. 9, p. 85–90.

Bowers, W.E., 1990, Geologic map of Bryce Canyon National Park and vicinity, southwestern Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-2108, 15 p., 1 plate, scale 1:24,000.

Bown, T.M., Hasiotis, S.T., Genise, J.F., Maldonado, F., and Bowers, E.M., 1997, Trace fossils of Hymenoptera and other insects, and paleoenvironments of the Claron Formation (Paleocene and Eocene), southwestern Utah, in Maldonado, F., and Nealey, L.D., editors, Geologic studies in the Basin and Range-Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1995: U.S. Geological Survey Bulletin 2153, p. 43–58.

Burden, C.B., and others, 2007, Ground-water conditions in Utah, spring of 2007: Utah Division of Water Resources, Utah Division of Water Rights, and U.S. Geological Survey Cooperative Investigations Report No. 46, 138 p.

Comley, H.H., 1945, Cyanosis in infants caused by nitrates in well water: Journal of the American Medical Association, v. 129, p. 112.

Croll, B.T., and Hayes, C.R., 1988, Nitrate and water supplies in the UK: Environmental Pollution, v. 50, no. 1-2, p. 163–187.

Cuello, C., Correa, P., Haenszel, W., Cordillo, G., Brown, C., Archer, M., and Tannenbaum, S., 1976, Gastric cancer in Columbia—Cancer risk and suspected environmental agents: Journal National Canadian Institute, v. 57, p. 1015–1020.

Davis, G.H., and Pollock, G.L., 2010, Geology of Bryce Canyon National Park, Utah, eds, Sprinkel, D.A., Chidsey Jr., T.C., and Anderson, P.B., *in* Geology of Utah's Parks and Monuments, Utah Geological Association Publication 28, p. 37–59.

Fan, A.M., Willhite, C.C., and Book, S.A., 1987, Evaluation of the nitrate drinking water standard with reference to infant methemoglobinemia and potential reproductive toxicology: Regulatory Toxicologic Pharmacology, v. 7, no. 2, p. 135–148.

Forman, D., 1985, Nitrates, nitrites and gastric cancer in Great Britain: Nature, v. 313, p. 620–625.

Fraser, P., Chilvers, C., Beral, V., and Hill, M.J., 1980, Nitrate and human cancer, a review: International Journal of Epidemiology, v. 9, p. 3–11.

Garfield County Economic Development Plan, 2019, Online: https://www.garfield.utah.gov/home/showdocument?id=788, accessed August 18, 2020.

Goldstrand, P.M., 1994, Tectonic development of Upper Cretaceous to Eocene strata of southwestern Utah: Geological Society of America Bulletin, v. 106, p. 145–154.

Hem, J.D., 1985, Study and interpretation of the chemical characteristics of natural water: U.S. Geological Survey Water-Supply Paper 2254, 263 p.

Knudsen, T.R., Biek, R.F., and Eaton, J.G., *in preparation*, Geologic map of Bryce Canyon National Park and vicinity: Utah Geological Survey Map, 2 plates, scale 1:24,000

Lawton, T.F., Pollock, S.L., and Robinson, R.A.J., 2003, Integrating sandstone petrology and nonmarine sequence stratigraphy—application to the Late Cretaceous fluvial systems of southwestern Utah, U.S.A.: Journal of Sedimentary Research, v. 73, no. 3, p. 389–406.

Mackin, J.H., and Rowley, P.D., 1976, Geologic map of The Three Peaks quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-1297, scale 1:24,000.

Maldonado, F., and Moore, R.C., 1995, Geologic map of the Parowan quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map 1762, 1 plate, scale 1:24,000.

Maldonado, F., and Williams, V.S., 1993a, Geologic map of the Parowan Gap quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map 1712, 1 plate, scale 1:24,000.

Maldonado, F., and Williams, V.S., 1993b, Geologic map of the Paragonah quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map 1713, 1 plate, scale 1:24,000.

Mullet, D.J., 1989, Interpreting the early Tertiary Claron Formation of southern Utah: Geological Society of America Abstracts with Programs, v.21, p. 120.

Ott, A.L., 1999, Detailed stratigraphy and stable isotope analysis of the Claron Formation, Bryce Canyon National Park, Washington State University, unpublished M.S. Thesis, 129 p.

Roberts, E.M., 2007, Facies architecture and depositional environments of the Upper Cretaceous Kaiparowits Formation, southern Utah: Sedimentary Geology, v. 197, p. 207–233.

Rowley, P.D., and Threet, R.L., 1976, Geologic map of the Enoch quadrangle, Iron County, Utah: U.S. Geological Survey Geologic Quadrangle Map GQ-1296, scale 1:24,000, modified by P.D. Rowley, 2003.

Rowley, P.D., Mehnert, H.H., Naeser, C.W., Snee, L.W., Cunningham, C.G., Steven, T.A., Anderson, J.J., Sable, E.G., and Anderson, R.E., 1994, Isotopic ages and stratigraphy of Cenozoic rocks of the Marysvale volcanic field and adjacent areas, west-central Utah: U.S. Geological Survey Bulletin 2071, 35 p.

Taneja, P., Labhasetwar, P., Nagarnaik, P., and Ensink, J.H.H, 2017, The risk of cancer as a result of elevated levels of nitrate in drinking water and vegetables in Central India, Journal of Water & Health, v. 15, p. 602-614.

Taylor, H.W., and Lijinsky, W., 1975, Tumor induction in rats by feeding heptamethyleneimine and nitrite in water: Cancer Research, v. 35, p. 505–812.

Thiros, S. and Brothers, 1993, Ground-water hydrology of the upper Sevier River basin, south-central Utah, aid simulation of ground-water flow in the valley-fill aquifer in Panguitch Valley, Department of Natural Resources Technical Publication 102, 121 p.

Town Charts, 2018, Bryce Canyon City: Online, http://www.towncharts.com/Utah/Demographics/Bryce-Canyon-City-town-UT-Demographics-data.html, accessed December 12, 2020.

U.S. Census Bureau, 2019, Population estimate program: Online, https://www.census.gov/quickfacts/garfieldcountyutah, accessed March 2021.

U.S. Environmental Protection Agency, 2006, Current drinking water standards: Online, http://www.epa.gov/safewater/mcl.html, accessed December 20, 2020.

Utah Division of Water Quality, 1998, Aquifer classification guidance document: Salt Lake City, unpublished Utah Division of Water Quality report, 9 p.

Utah Division of Water Rights, 2019, Water use data from the Utah Water Use Program: Online, https://waterrights.utah.gov/distinfo/wuse.asp, accessed December 2020.

Utah Governor's Office of Management and Budget, 2012, Municipal population projections 2010-2060: Online, accessed December 12, 2020, https://mountainland.org/img/Data/Projections/GOMBSmallAreaProjections.pdf.

APPENDIX A

WATER-QUALITY DATA

(Site ID numbers shown on plate 1)

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Site Type	Site Name	pH	pH Lab	Temp (°C)	Conductivity Field (µS/cm)	Conductivity Lab (µS/cm)	TDS (mg/L)	Phosphate (mg/L)	Ammonia(N) (mg/L)	Nitrite + Nitrate (mg/L)	TSS (mg/L)	Ca (mg/L)	Mg (mg/L)
BC6S	spring	Dipping Vat	7.9	7.07	8	470	449	226	0.0035	<0.05	0.352	<4	43.6	33.5
BC3S	spring	Hatch	8.12	7.07	11.4	428	414	214	0.0202	<0.05	0.504	199	48.9	25
BC15S	spring	Lower Berry	7.94	6.82	12.5	398	448	268	0.031	<0.05	<0.1	<4	56.8	17.9
BC8S	spring	Swamp	7.72	-	7.3	590	-	338	-	-	<0.1	-	-	-
BC10S	spring	NPS Bryce Spring 1	7.69	-	8.8	517	-	315	-	-	-	-	-	-
BC31S	spring	Tom Best Spring	7.92	6.82	10.8	332	333	198	0.159	<0.05	0.105	<4	40.4	15.6
BC2S	spring	Tropic 1	8.09	7.68	8.7	530	519	254	0.0042	<0.05	0.249	<4	39	47.8
BC4S	spring	Tropic 2	8.45	7.03	10.4	360	517	220	0.0032	<0.05	0.143	<4	34.4	35.2
BC17S	spring	Upper Berry	8.1	7.47	12.5	569	670	394	0.032	<0.05	-		64.1	45.2
BC62S	spring	Whiteman Spring	7.54	7.80	10.5	560	561	294	0.0198	<0.05	<0.1	152	61.6	41
BC34S	spring	Mossy Spring 1	7.65	6.77	10.6	479	481	266	-	-	-	490	45.6	35.5
BC35S	spring	Mossy Spring Cave	8.3	8.08	7.8	472	455	232	0.018	<0.05	0.367	65.6	42.3	35.2
BC36S	spring	Mossy Spring 3	7.97	-	10.1	531	-	324	-	-	-	-	-	-
BC11S	spring	NPS 4	7.45	6.87	8.2	510	504	254	0.0043	<0.05	<0.1	<4	54.8	37.4
BC53S	spring	Waterstop	7.8	7.68	7.6	455	441	220	<0.003	<0.05	0.223	<4	42.2	35.6
BC27W	well	Airport	8.13	8.02	14.3	469	517	262	0.0033	<0.05	0.111	<4	55.5	37.9
BC24W	well	BLM 2	8.2	7.04	-	365	1840	186	-	-	<0.1	10	28.8	23.5
BC19W	well	Kings Campground	8.45	7.07	9.2	371	371	192	<0.003	<0.05	<0.1	<4	34.3	28.2
BC28W	well	Landfill 1	7.57	6.82	10.2	426	426	234	0.033	<0.05	0.991	<4	35.9	28.7
BC29W	well	Landfill 2	7.67	6.99	10.8	561	561	308	0.034	<0.05	0.702	12.8	50.7	36.7
BC30W	well	Landfill 3	7.91	7.26	9.6	540	540	282	0.0151	<0.05	0.292	<4	55.3	39.1
BC13W	well	Poe	7.13	6.65	9.9	884	884	530	0.147	<0.05	<0.1	215	118	50.8
BC26W	well	Rich	8.01	7.13	12	585	585	310	0.024	<0.05	0.416	<4	55.8	36.1
BC7W	well	Ruby 4	8.18	6.85	16.3	345	333	182	-	-	0.602	-	50.9	13.7
BC20W	well	Ruby 1	-	7.06	-	542	546	286	<0.003	<0.05	<0.1	5.6	-	-
BC21W	well	Ruby 2	7.85	7.24	7.4	530	548	286	<0.003	<0.05	<0.1	<4	56.8	40.6
BC22W	well	Ruby 3	8	7.07	7.1	555	548	282	0.0031	<0.05	<0.1	<4	56.2	40.7
BC25W	well	UDOT	7.87	7.48	12.9	520	506	252	0.0045	<0.05	0.43	<4	48.8	34.4
BC12W	well	USFS Daves Hollow	7.51	7.07	8.1	664	619	324	0.0036	<0.05	<0.1	<4	69.8	43.5
BC37W	well	Ruby 5	8.33	6.78	12.7	309	328	192	0.0048	0.164	1.01	13.6	48.7	14.6
BC38W	well	Ruby 6	7.8	7.06	9.2	390	377	194	-	-	0.958	<4	50.3	15.7
BC39W	well	Ruby 7	-	-	-	-	-	-	-	-	0.953	-	-	-
BC40W	well	Elgin Elk Preserve	7.55	7.06	8.8	466	446	224	0.0074	<0.05	1.47	<4	32.8	31.2
BC44W	well	NPS 1	7.62	7.06	7.9	536	508	254	0.0039	<0.05	<0.1	<4	49.8	35.9
BC45W	well	NPS 3	7.21	-	7.8	594	-	362	-	-	-	-	-	-
BC46W	well	NPS 2	7.77	-	11.6	568	-	346	0.0045	<0.05	<0.1	-	-	-
BC48W	well	SITLA	7.72	6.55	9.2	928	931	512	0.0118	<0.05	0.312	<4	37.5	84.7
BC49W	well	Cottonwood	10.8	7.79	10.8	782	761	416	0.0043	<0.05	<0.1	4.8	70.5	58.8
BC51W	well	Bristlecone	7.47	7.78	9.4	515	674	354	0.021	<0.05	1.06	<4	55	43.4
BC61S	spring	Showalter Spring	-	8.01	-	536	620	384	-	-	-	<4	87.3	21.9

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Site Type	Site Name	pH	pH Lab	Temp (°C)	Conductivity Field (µS/cm)	Conductivity Lab (µS/cm)	TDS (mg/L)	Phosphate (mg/L)	Ammonia(N) (mg/L)	Nitrite + Nitrate (mg/L)	TSS (mg/L)	Ca (mg/L)	Mg (mg/L)
BC60S	spring	Middle Berry	-	8.22	-	-	467	282	0.058	<0.05	0.325	15.6	58.1	17.1
BC64S	spring	Mossy Trail	8.3	8.20	10.4	453	486	246	0.0036	<0.05	0.349	16.4	47.3	36.6
BC65W	well	Sitla 2	8.03	7.64	11.9	411	430	210	0.033	<0.05	0.564	54.4	42	29
BC66W	well	Smith	7.66	7.03	10.6	478	478	256	0.0174	<0.05	0.231	<4	63.1	22.7
BC67W	well	Anderson	7.62	6.94	9.5	605	608	356	0.0088	<0.05	<0.1	7.6	60.4	40.5
BC68S	spring	Yovimpa	7.52	7.07	6.5	475	455	236	-	-	0.182	<4	57.8	29.1
BC70S	spring	Iron	6.74	-	8.9	596	-	364	-	-	<0.1	-	-	-
BC77S	spring	Ingram	7.77	-	6.7	503	-	307	-	-	0.3	-	-	-
BC84W	well	Highway 12 North Well	-	7.06	-	435	404	198	-	-	<0.1	<4	49.4	18.4
BC115W	well	SITLA Cottonwood Creek Well	-	-	8.4	240	-	151	-	-	-	-	-	-
BC116W	well	16068 Stock Well	-	-	7.7	523	-	329	-	-	-	-	-	-
BC117W	well	432226 Stock Well	-	-	7.4	447	-	282	-	-	-	-	-	-
BC118W	well	16066 Stock Well	-	-	7.1	250	-	158	-	-	-	-	-	-
BC119S	spring	Reynolds Spring	-	-	8.4	408	-	257	-	-	-	-	-	-
BC120W	well	432247 Stock Well	-	-	8.3	485	-	306	-	-	-	-	-	-
3250	well	UDAF site*	8.5	-	9.8	364	-	218	nd	nd	nd	-	28.86	27.18
374205112091501	well	NWIS** site	8.1	-	-	-	-	168	-	-	-	-	-	-
374205112091501	well	NWIS site	8.1	-	12	439	-	238	-	-	-	-	-	-
374205112091501	well	NWIS site	7.7	-	15	426	-	226	-	-	-	-	-	-
374205112091501	well	NWIS site	7.6	-	10	415	-	251	-	-	-	-	-	-
374205112091501	well	NWIS site	7.2	-	19.3	536	-	287	-	-	-	-	-	-
374205112091501	well	NWIS site	7.5	-	18.1	542	-	245	-	-	-	-	-	-
374855112054501	spring	NWIS site	-	-	-	445	-	271	-	-	-	-	-	-
374846112055001	well	NWIS site	7.8	-	10	408	-	246	-	-	-	-	-	-
374846112055001	well	NWIS site	-	-	10	375	-	233	-	-	-	-	-	-
374501112022901	well	NWIS site	7.7	-	7.5	440	-	224	-	-	-	-	-	-
373237112162101	well	NWIS site	7.8	-	5.7	445	-	34	-	-	-	-	-	-
373237112162101	well	NWIS site	7.7	-	6	410	-	214	-	-	-	-	-	-
373456112133501	well	NWIS site	8	-	6	455	-	243	-	-	-	-	-	-
373508112151701	well	NWIS site	7.5	-	6.5	435	-	28	-	-	-	-	-	-
373508112151701	well	NWIS site	7.6	-	7	475	-	255	-	-	-	-	-	-
373533112150901	well	NWIS site	7.6	-	6.5	390	-	6	-	-	-	-	-	-
373638112151801	well	NWIS site	7.6	-	7	485	-	297	-	-	-	-	-	-
373638112151801	well	NWIS site	7.5	-	7.5	505	-	271	-	-	-	-	-	-
373754112123901	well	NWIS site	7.5	-	7	520	-	267	-	-	-	-	-	-
374245112123901	well	NWIS site	7.5	-	-	840	-	422	-	-	-	-	-	-
374150112111501	well	NWIS site	7.4	-	-	480	-	260	-	-	-	-	-	-
374120112084201	well	NWIS site	7.8	-	9.5	305	-	167	-	-	-	-	-	-

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	Alkalinity (mg/L CaCO3)	CO3 solids(mg/L)	HCO3 (mg/L)	CO2(mg/L)	Hardness (mg/L)	Turbidity (NTU)	Al (mg/L)	As (µg/L)	B (µg/L)	Ba (mg/L)	Be (mg/L)	Br (µg/L)
BC6S	7.07	<1	6.17	<20	232	139	283	39.7	247	0.15	-	-	-	-	-	-
BC3S	5.04	<1	8.62	<20	196	118	239	33.6	225	25.2	-	-	-	-	-	-
BC15S	14.7	<1	8.74	<20	205	123	250	62.2	216	1.41	-	-	-	-	-	-
BC8S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC10S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC31S	11.3	1.4	3.59	<20	161	96.4	196	49	165	0.933	-	-	-	-	-	-
BC2S	3.93	<1	4.15	<20	273	164	333	11.4	294	0.485	-	-	-	-	-	-
BC4S	2.59	<1	3.5	<20	220	132	268	40.7	231	0.636	-	-	-	-	-	-
BC17S	21.9	3.86	15.2	<20	336	202	410	23	346	93.9	-	-	-	-	-	-
BC62S	3.23	<1	3.57	<20	298	179	363	9.4	323	119	-	-	-	-	-	-
BC34S	5.19	1.82	8.18	<20	253	152	309	86.9	260	237	-	-	-	-	-	-
BC35S	4.47	1.82	6.88	<20	236	141	288	3.9	251	83.3	-	-	-	-	-	-
BC36S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC11S	2.93	<1	3.5	<20	265	159	323	71.5	291	0.302	-	-	-	-	-	-
BC53S	2.94	<1	3.56	<20	230	138	281	9.49	252	0.365	-	-	-	-	-	-
BC27W	3.36	<1	3.5	<20	270	162	329	5.06	295	0.23	-	-	-	-	-	-
BC24W	10.6	1.98	9.13	<20	165	99.2	202	30.3	169	14.1	-	-	-	-	-	-
BC19W	3.04	1.99	4.45	<20	181	109	221	31	202	0.392	-	-	-	-	-	-
BC28W	15.6	1.46	8.6	<20	206	123	251	62.1	208	0.33	-	-	-	-	-	-
BC29W	14.3	2.02	9.54	<20	270	162	329	55.4	278	2.68	-	-	-	-	-	-
BC30W	6.27	1.38	6.11	<20	270	162	329	29.5	299	0.214	-	-	-	-	-	-
BC13W	7.27	1.37	10.1	111	358	215	437	162	504	133	-	-	-	-	-	-
BC26W	16.9	1.21	20.8	<20	264	158	322	38.7	288	0.828	-	-	-	-	-	-
BC7W	2.68	<1	3.5	<20	160	95.8	195	45.1	184	0.485	-	-	-	-	-	-
BC20W	-	-	3.64	<20	292	175	356	50.3	-	2.4	-	-	-	-	-	-
BC21W	2.88	<1	3.53	<20	288	173	351	33.1	309	0.284	-	-	-	-	-	-
BC22W	2.71	<1	3.5	<20	273	164	333	46.6	308	0.143	-	-	-	-	-	-
BC25W	9.06	1.23	8.3	<20	241	145	295	15.9	254	0.339	-	-	-	-	-	-
BC12W	2.73	<1	3.55	<20	322	193	393	55.1	353	16.1	-	-	-	-	-	-
BC37W	2.94	<1	9.84	<20	155	93.1	189	51.5	182	1.72	-	-	-	-	-	-
BC38W	3.49	<1	12.1	<20	169	102	207	29.4	190	0.49	-	-	-	-	-	-
BC39W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC40W	11.9	1.07	10.6	<20	203	132	248	35.3	210	0.566	-	-	-	-	-	-
BC44W	2.93	<1	3.5	<20	268	161	326	46.5	272	0.451	-	-	-	-	-	-
BC45W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC46W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC48W	53.2	2.89	29.3	34	417	250	509	234	443	<0.1	-	-	-	-	-	-
BC49W	16.4	1.29	12.4	<20	385	231	470	12.3	418	32.7	-	-	-	-	-	-
BC51W	22	1.13	47.3	<20	266	159	324	8.73	316	2.43	-	-	-	-	-	-
BC61S	15.1	5.3	9.38	<20	319	191	389	6.13	308	2.02	-	-	-	-	-	-

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	Alkalinity (mg/L CaCO3)	CO3 solids(mg/L)	HCO3 (mg/L)	CO2(mg/L)	Hardness (mg/L)	Turbidity (NTU)	Al (mg/L)	As (µg/L)	B (µg/L)	Ba (mg/L)	Be (mg/L)	Br (µg/L)
BC60S	12.2	<1	10.5	<20	221	133	270	2.61	216	6.55	-	-	-	-	-	-
BC64S	5.22	1.94	7.39	<20	248	149	302	3.11	269	2.29	-	-	-	-	-	-
BC65W	7.04	1.56	3.76	<20	213	128	260	9.85	224	3.01	-	-	-	-	-	-
BC66W	5.77	1.12	6.84	<20	240	144	293	45.3	251	0.486	-	-	-	-	-	-
BC67W	21.4	2.07	8.49	<20	304	183	371	70.7	318	13.7	-	-	-	-	-	-
BC68S	2.03	<1	3.5	<20	244	147	298	41.9	264	0.117	-	-	-	-	-	-
BC70S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC77S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC84W	5.86	1.69	7.71	<20	190	114	232	33	199	13.9	-	-	-	-	-	-
BC115W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC116W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC117W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC118W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC119S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC120W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3250	4.78	1.07	nd	2.97	-	-	3.76	-	3.3	-	nd	nd	nd	0.31	nd	-
374205112091501	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374205112091501	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374205112091501	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374205112091501	-	-	-	-	-	-	-	-	-	-	-	-	60	-	-	-
374205112091501	-	-	-	-	-	-	-	-	-	-	-	0.31	-	-	-	0.035
374205112091501	-	-	-	-	-	-	-	-	-	-	-	0.62	-	-	-	0.037
374855112054501	-	-	-	-	-	-	-	-	-	-	-	-	100	-	-	-
374846112055001	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374846112055001	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-	-
374501112022901	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
373237112162101	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
373237112162101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
373456112133501	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-
373508112151701	-	-	-	-	-	-	-	-	-	-	-	-	10	-	-	-
373508112151701	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
373533112150901	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	-
373638112151801	-	-	-	-	-	-	-	-	-	-	-	-	20	-	-	-
373638112151801	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
373754112123901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374245112123901	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374150112111501	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
374120112084201	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Cd (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Li (mg/L)	Mn (µg/L)	Mo (µg/L)	Pb (mg/L)	Se (µg/L)	Si (mg/L SiO2)	U (µg/L)	V (mg/L)	Zn (mg/L)	Pesticides
BC6S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC3S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC15S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC8S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC10S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC31S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC2S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC4S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC17S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC62S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC34S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC35S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC36S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC11S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC53S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC27W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC24W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC19W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC28W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC29W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC30W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC13W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC26W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC7W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC20W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC21W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC22W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC25W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC12W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC37W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC38W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC39W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC40W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC44W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC45W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC46W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC48W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC49W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC51W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC61S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix A. *Water quality data for Johns and Emery Valleys, Garfield County, Utah.*

Site ID	Cd (mg/L)	Co (mg/L)	Cr (mg/L)	Cu (mg/L)	F (mg/L)	Fe (µg/L)	Li (mg/L)	Mn (µg/L)	Mo (µg/L)	Pb (mg/L)	Se (µg/L)	Si (mg/L SiO2)	U (µg/L)	V (mg/L)	Zn (mg/L)	Pesticides
BC60S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC64S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC65W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC66W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC67W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC68S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC70S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC77S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC84W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC115W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC116W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC117W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC118W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC119S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BC120W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3250	nd	nd	nd	nd	-	nd	0.13	nd	nd	nd	nd	-	-	nd	nd	see footnote
374205112091501	-	-	-	-	0.1	160	-	-	-	-	-	12	-	-	-	-
374205112091501	-	-	-	-	-	100	-	-	-	-	-	8.8	-	-	-	-
374205112091501	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-
374205112091501	-	-	-	-	0.1	580	-	25	-	-	< 1	9	-	-	-	-
374205112091501	-	-	-	-	0.13	5	-	< 0.16	0.38	-	0.34	7.61	1.59	-	-	-
374205112091501	-	-	-	-	0.17	< 10	-	0.21	0.364	-	0.31	7.86	1.63	-	-	-
374855112054501	-	-	-	-	0.3	20	-	< 10	-	-	-	27	-	-	-	-
374846112055001	-	-	-	-	0.2	-	-	-	-	-	-	30	-	-	-	-
374846112055001	-	-	-	-	0.3	8	-	< 1	-	-	< 1	29	-	-	-	-
374501112022901	-	-	-	-	0.2	< 10	-	< 1	-	-	-	7.4	-	-	-	-
373237112162101	-	-	-	-	0.1	10	-	-	-	-	-	6.3	-	-	-	-
373237112162101	-	-	-	-	0.2	< 9	-	< 3	-	-	-	6.1	-	-	-	-
373456112133501	-	-	-	-	0.2	< 10	-	< 1	-	-	-	6.8	-	-	-	-
373508112151701	-	-	-	-	0.2	20	-	-	-	-	-	7.1	-	-	-	-
373508112151701	-	-	-	-	0.3	10	-	< 3	-	-	-	6.9	-	-	-	-
373533112150901	-	-	-	-	0.2	< 10	-	-	-	-	-	6.4	-	-	-	-
373638112151801	-	-	-	-	0.2	< 10	-	< 1	-	-	-	6.8	-	-	-	-
373638112151801	-	-	-	-	0.3	< 9	-	< 3	-	-	-	6.7	-	-	-	-
373754112123901	-	-	-	-	0.5	< 10	-	-	-	-	-	6.9	-	-	-	-
374245112123901	-	-	-	-	0.4	< 10	-	-	-	-	-	9.3	-	-	-	-
374150112111501	-	-	-	-	0.2	100	-	50	-	-	-	7.9	-	-	-	-
374120112084201	-	-	-	-	0.6	30	-	-	-	-	-	7.2	-	-	-	-

TDS = total dissolved solids
TSS = total suspended solids
NTU = nephelometric turbidity units
nd = non-detect

*Well water was analyzed for these pesticides by the Utah Department of Agriculture and Food having no detect: Hexachlorocyclopentadiene Alpha Chlordane 2,4,5-TP (Silvex) Hexachlorobenzene Dieldrin Picloram Simazine * Endrin Aldicarb Atrazine * Methoxychlor Aldicarb sulfone Gamma-Lindane Chlordane "T" Aldicarb sulfoxide Heptachlor Toxaphene "T" Carbofuran Alachlor * Prometon Methomyl Aldrin Dicamba Oxamyl (Vydate) Heptachlor-Epoxide 2,4-D 3-OH Carbofuran Gamma Chlordane PCP 3-Keto Carbofuran Disulfton Diazinon Metolachlor
**Data from USGS National Water Information System

APPENDIX B

POTENTIAL CONTAMINANT INVENTORY DATA

Appendix B. *Potential contaminant inventory for Johns and Emery Valleys, Garfield County, Utah.*

FIELD ID	TYPE	Description of potential contaminant	Pollutant
1	AFO[1]	equestrian campground	fertilizers, manure, nitrates
2	Waste Disposal	RV dump station	metals, solvents, nitrates
3	AFO	horse corral	fertilizers, manure, nitrates
4	Former AFO	abandoned corral	fertilizers, manure, nitrates
5	AFO	corral	fertilizers, manure, nitrates
6	Service station	service station	solvents, petroleum
7	Business	RV park	metals, solvents, nitrates
8	AFO	horse corral	fertilizers, manure, nitrates
9	Junk Yard/Salvage	junk site	metals, solvents, petroleum
10	AFO	corral	fertilizers, manure, nitrates
11	Business	hotel, restaurant	solvents
12	AFO	horse corral, rodeo arena	fertilizers, manure, nitrates
13	AFO	corral	fertilizers, manure, nitrates
14	AFO	corral	fertilizers, manure, nitrates
15	Government	rest area	solvents, nitrates
16	Government	guard station	metals, solvents, petroleum
17	AFO	corral	fertilizers, manure, nitrates
18	Junk Yard/Salvage	personal junk yard	metals, solvents, petroleum
19	Former AFO	abandoned corral	fertilizers, manure, nitrates
20	Junk Yard/Salvage	junk site	metals, solvents, petroleum
21	Former AFO	abandoned corral	fertilizers, manure, nitrates
22	Mining	inactive borrow pit	metals, solvents, petroleum
23	Former AFO	abandoned corral	fertilizers, manure, nitrates
24	Business, AFO	wildlife museum, ATV storage, exotic animal corral	fertilizers, manure, nitrates
25	Mining	inactive borrow pit	metals, solvents, petroleum
26	Mining	inactive borrow pit	metals, solvents, petroleum
27	Business	hotel, restaurant	solvents
28	AFO	mule/horse corral	fertilizers, manure, nitrates
29	Former AFO	abandoned corral	fertilizers, manure, nitrates
30	Government	waste disposal, automotive storage/scrap yard	metals, solvents, petroleum
31	Junk Yard/Salvage	junk site	metals, solvents, petroleum
32	Mining	gravel pit	metals, solvents, petroleum
33	Government	maintenance yard, paint shop, automotive repair	metals, solvents, petroleum
34	Mining	inactive borrow pit	metals, solvents, petroleum
35	Waste Disposal	sewage lagoons	metals, solvents, nitrates
36	Government	radio towers	metals, solvents
37	Industry	power sub station	PCBs
38	Former AFO	abandoned corral	fertilizers, manure, nitrates
39	Junk Yard/Salvage	junk site	metals, solvents, petroleum
40	AFO	coral	fertilizers, manure, nitrates
41	Business	hotel, restaurant	solvents
42	Service station	abandoned service station	metals, solvents, petroleum
43	AFO	elk preserve	fertilizers, manure, nitrates
44	Waste Disposal	RV dump station	metals, solvents, nitrates
45	Mining	inactive borrow pit	metals, solvents, petroleum
46	AFO	horse corral	fertilizers, manure, nitrates
47	AFO	corral	fertilizers, manure, nitrates
48	Mining	inactive borrow pit	metals, solvents, petroleum
49	Junk Yard/Salvage	auto scrap yard/storage	metals, solvents, petroleum
50	AFO	horse corrals	fertilizers, manure, nitrates
51	Business	RV park	metals, solvents, nitrates
52	Waste Disposal	RV dump station	metals, solvents, nitrates
53	Waste Disposal	sewage lagoons	metals, solvents, nitrates
54	Business, Large Lawn	hotel, large lawns	pesticides, fertilizer
55	Mining	inactive borrow pit	metals, solvents, petroleum
56	Government	fire station	metals, solvents, petroleum
57	Business	maintenance yard, automotive repair	metals, solvents, petroleum
58	Business	restaurants	solvents
59	Service station	service station	solvents, petroleum
60	Large Lawn	park	pesticides, fertilizer

Appendix B. *Potential contaminant inventory for Johns and Emery Valleys, Garfield County, Utah.*

FIELD ID	TYPE	Description of potential contaminant	Pollutant
61	Waste Disposal	RV dump station	metals, solvents, nitrates
62	Business	gift shop, restaurants	solvents
63	AFO	horse corral	fertilizers, manure, nitrates
64	Junk Yard/Salvage	personal junk yard	metals, solvents, petroleum
65	Industry	airport	metals, solvents, petroleum
66	Business	hotel, restaurants	solvents
67	Business, Large Lawn	restaurant, large lawn	pesticides, fertilizer
68	AFO	corral, rodeo grounds	fertilizers, manure, nitrates
69	Business, Large Lawn	hotel, large lawn	solvents, pesticides, fertilizers
70	Business	hotel	solvents
71	Industry	power sub station	PCBs
72	Business	abandoned restaurant	metals, solvents
73	Large Lawn	cemetary	pesticides, fertilizer
74	Business	RV park	metals, solvents, nitrates
75	Shooting range	shooting range	metals
76	Industry	cell tower	metals, solvents
77	AFO	corral	fertilizers, manure, nitrates
78	Junk Yard/Salvage	junk site	metals, solvents, petroleum
79	Former AFO	abandoned corral	fertilizers, manure, nitrates
80	Industry	cell tower	metals, solvents
81	Waste Disposal	landfill	metals, solvents, petroleum
82	Former AFO	abandoned corral	fertilizers, manure, nitrates
83	Junk Yard/Salvage	junk site	metals, solvents, petroleum
84	Former AFO	abandoned corral	fertilizers, manure, nitrates
85	Junk Yard/Salvage	junk site	metals, solvents, petroleum
86	Former AFO	abandoned corral	fertilizers, manure, nitrates
87	AFO	corral	fertilizers, manure, nitrates
88	AFO	corral	fertilizers, manure, nitrates
89	AFO	corral	fertilizers, manure, nitrates
90	Former AFO	abandoned corral	fertilizers, manure, nitrates
91	Mining	gravel pit	metals, solvents, petroleum
92	AFO	corral	fertilizers, manure, nitrates
93	AFO	corral	fertilizers, manure, nitrates
94	AFO	corral	fertilizers, manure, nitrates
95	AFO	corral	fertilizers, manure, nitrates
96	Former AFO	abandoned corral	fertilizers, manure, nitrates
97	AFO	corral	fertilizers, manure, nitrates
98	Former AFO	abandoned corral	fertilizers, manure, nitrates
99	Junk Yard/Salvage	personal junk yard	metals, solvents, petroleum
100	AFO	corral	fertilizers, manure, nitrates
101	AST[2]	above-ground storage tank	metals, solvents, petroleum
102	AST	above-ground storage tank	metals, solvents, petroleum
103	AST	above-ground storage tank	metals, solvents, petroleum
104	AST	above-ground storage tank	metals, solvents, petroleum

[1] - Animal Feed Operation

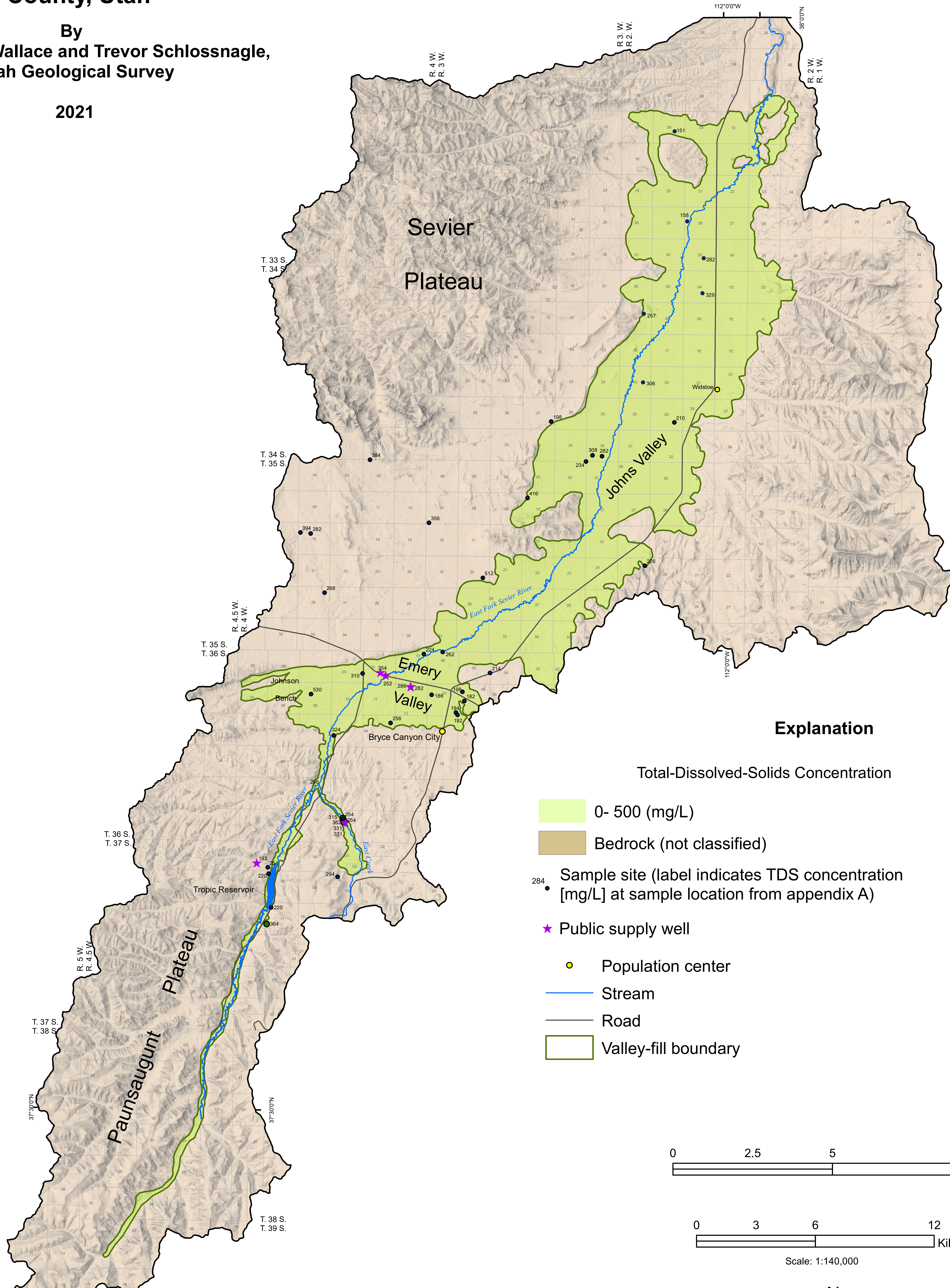
[2] - Above-ground Storage Tank

Plate 1

Total Dissolved Solids, Johns and Emery Valleys, Garfield County, Utah

By
Janae Wallace and Trevor Schlossnagle,
Utah Geological Survey

2021



Explanation

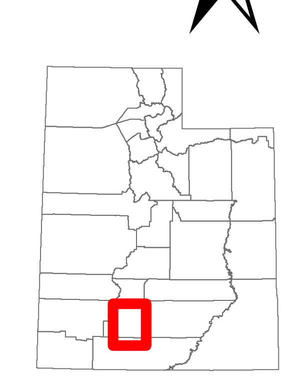
Total-Dissolved-Solids Concentration

- 0- 500 (mg/L)
- Bedrock (not classified)
- 284 Sample site (label indicates TDS concentration [mg/L] at sample location from appendix A)
- ★ Public supply well
- Population center
- Stream
- Road
- Valley-fill boundary

0 2.5 5 10 Miles

0 3 6 12 Kilometers

Scale: 1:140,000



Study Area

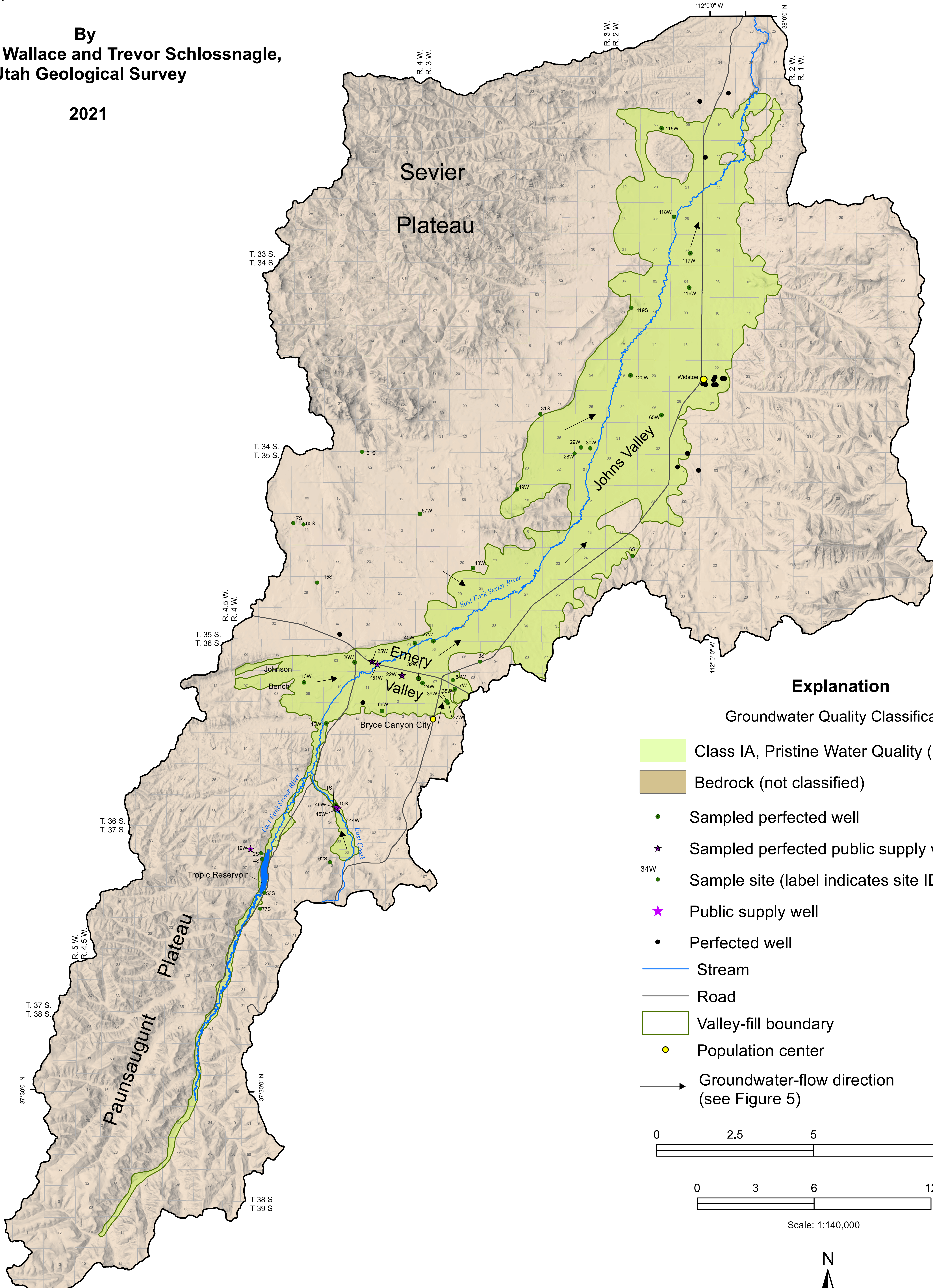
This map was created from GIS files. Basemap constructed from features obtained from the Utah AGRC.
Projection: UTM
Datum: NAD 83 Zone 12N
Cartography by Nathan Payne

Plate 2

Groundwater Quality Classification, Johns and Emery Valleys, Garfield County, Utah

By
Janae Wallace and Trevor Schlossnagle,
Utah Geological Survey

2021



Explanation

Groundwater Quality Classification

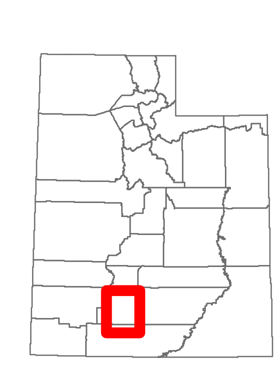
- Class IA, Pristine Water Quality (TDS: 0- 500 mg/L)
- Bedrock (not classified)
- Sampled perfected well
- Sampled perfected public supply well
- 34W — Sample site (label indicates site ID from appendix A)
- Public supply well
- Perfected well
- Stream
- Road
- Valley-fill boundary
- Population center
- Groundwater-flow direction (see Figure 5)

0 2.5 5 10 Miles

0 3 6 12 Kilometers

Scale: 1:140,000

N



Study Area

UTAH DNR GEOLOGICAL SURVEY

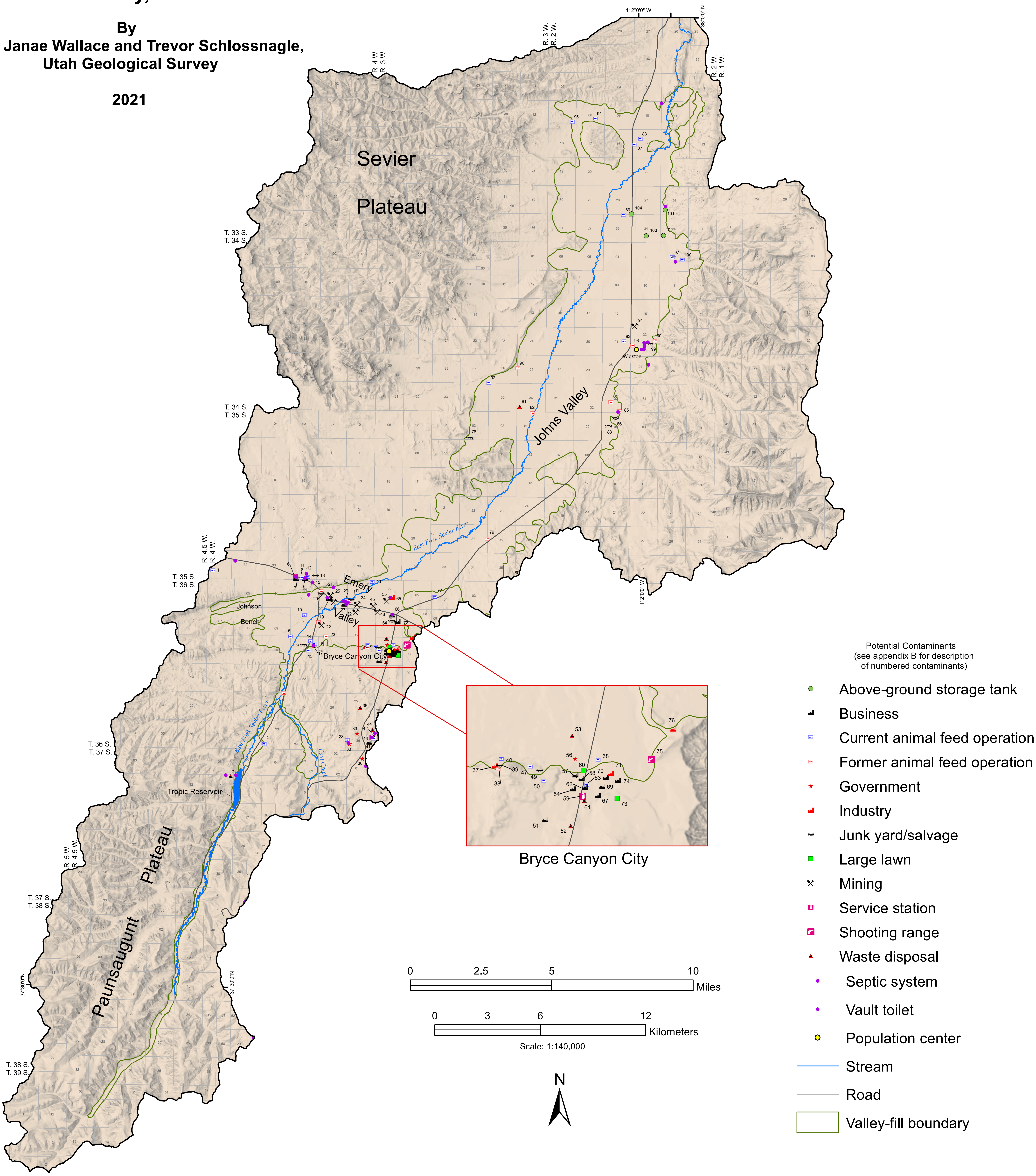
This map was created from GIS files. Basemap constructed from features obtained from the Utah AGRC.
Projection: UTM
Datum: NAD 83 Zone 12N
Cartography by Nathan Payne

Plate 3

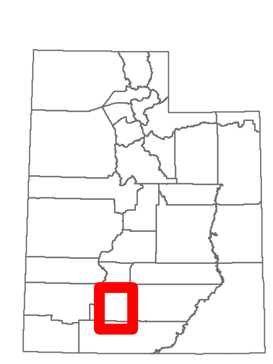
Potential Contaminant Sources, Johns and Emery Valleys, Garfield County, Utah

By
Janae Wallace and Trevor Schlossnagle,
Utah Geological Survey

2021



This map was created from GIS files. Basemap constructed from features obtained from the Utah AGRC.
Projection: UTM
Datum: NAD 83 Zone 12N
Cartography by Nathan Payne



Study Area